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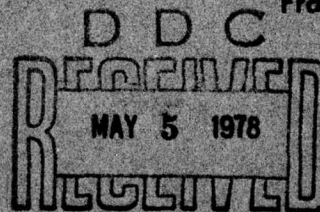
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TECHNICAL REPORT  
NATICK/TR-78/011

## ACCORDION SHELTER HARDWARE ANALYSIS

Predrag Shopalovich  
Franklin Barca



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February 1978

UNITED STATES ARMY  
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NATICK, MASSACHUSETTS 01760



Aero-Mechanical Engineering Laboratory

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) This report presents the results of an investigation into some of the hardware difficulties experienced with the accordion shelter during field tests. The accordion shelter is a prototype rigid-wall, general purpose, expandable military shelter. In the closed transportation configuration the shelter serves as its own shipping container and conforms to the dimensional and strength requirements of the International Organization for Standardization Type IC freight container. In the habitation mode the container expands from both sides to form an inclosed, environmentally controlled, lighted shelter approximately 2.4		

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20. ABSTRACT (cont'd)

metres high by 2.4 metres wide by 15.2 metres long.

The main problem areas are identified as container jacks, floor jacks, leveling system, and expansion system. The specific causes of the problems are identified and solutions to the problems are proposed.

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# PREFACE

This study was conducted by the US Army Natick Research and Development Command under Project Number 1L762723A427, Task Number 01, Work Unit 005 entitled, "Shelter Technology - Development of Improved Hardware for Tactical Shelters."

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## ACCORDION SHELTER HARDWARE ANALYSIS

### INTRODUCTION

The accordion shelter is a prototype unit designed and fabricated by the Brunswick Corporation, under contract to the Natick Research and Development Command, to meet the military need for a general-purpose, rigid-wall shelter with a large expansion ratio.

In the closed transportation configuration, Figure 1, the shelter serves as its own shipping container and conforms to the dimensional and strength requirements of the International Organization for Standardization (ISO) Type IC freight container. It measures nominally 2.4 metres (8 feet) high by 2.4 metres (8 feet) wide by 6 metres (20 feet) long and has a mass of approximately 3855 kilograms (8500 pounds). It can be transported by ship, truck, rail, and air and is compatible with both military and commercial freight handling equipment.

In the habitation mode, Figure 2, the shelter expands from both sides of the closed shipping mode much in the manner of an accordion to form an inclosed, environmentally controlled, lighted shelter approximately 2.4 metres (8 feet) high by 6 metres (20 feet) wide by 15.2 metres (50 feet) long with about 93 square metres (1,000 square feet) of usable floor space. Potential uses of the shelter include barracks, hospital wards, administrative and recreation areas.

The shelter is constructed primarily of two types of strong, lightweight, composite panels. The rigid panels used in the central core, expanding floor, and folding end walls have a resin-impregnated paper honeycomb core bonded to aluminum face sheets. The creased panels which form the flexible folding accordion shell have a urethane core bonded to 0.076-millimetre (0.003-inch) embossed steel skins protected with a 0.025-millimetre (0.001-inch) Tedlar film coating.

Two prototype units have been fabricated. The first prototype accordion shelter was field tested by the US Army Arctic Test Center at Fort Greeley, Alaska, from December 1974 to April 1975. The test was conducted by representative user personnel in temperatures ranging from -1°C to -45°C (30°F to -49°F) and in windspeeds up to 49 knots. The purpose of the test was to determine if the shelter was adequate for arctic use with respect to transportability, habitability, and function. It was concluded that the shelter was generally acceptable but that improvements were required for erection and striking operations under field conditions. Complete details and results of the field test are contained in a technical report by Beavin, Reference 1.

1. Beavin, John D., Cpt, Engineer Design Test of Air Transportable Shelter, Report No. 7-ES-975-000-005, 22 May 1975, US Army Arctic Test Center, APO Seattle 98733.

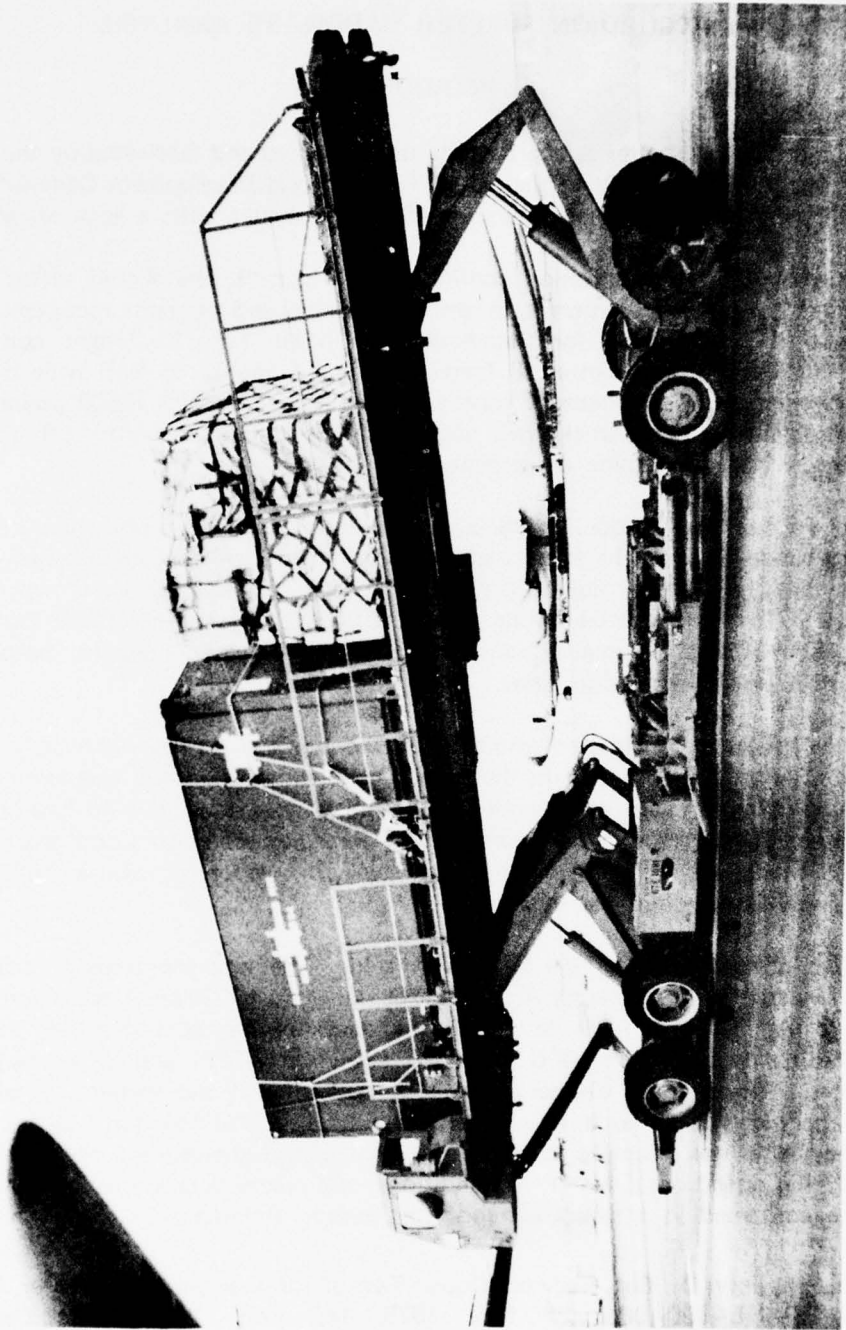


Figure 1. Accordion Shelter, Transportation Configuration. Closed Shelter Being Loaded onto Aircraft.



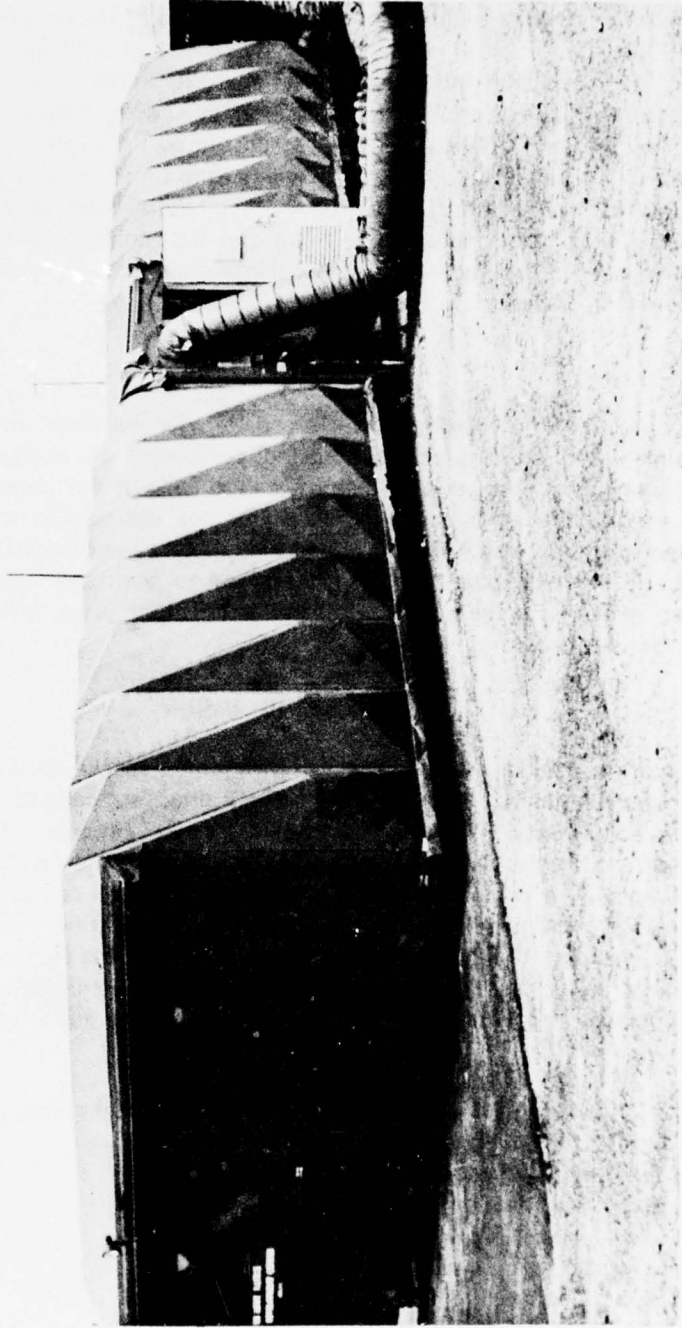


Figure 2. Accordion Shelter, Expanded Habitation Configuration. Both Shells Expanded from Central Core to Form Shelter.

The shelter was further field tested at Fort Hood, Texas, from August 1975 to November 1975. Test conditions were generally moderate with average temperatures of 21°C (70°F) and maximum wind gusts of less than 20 knots. The purpose of this test was also to determine if the shelter was adequate with respect to transportability, habitability and function. The unit was transported by helicopter, truck, and dolly over various terrains. It was erected and struck numerous times in daylight and at night. It was concluded that shelter transportability and habitability were satisfactory but that the erection and striking process was too difficult and time-consuming and that some of the hardware items were structurally inadequate. Details of the Fort Hood test are contained in a test report by Alexander, Reference 2.

## OBJECTIVE

In response to the difficulties experienced by user personnel during field tests, the Natick Research and Development Command conducted an engineering study of the accordion shelter. The purpose of the study was to analyze the causes of the deficiencies and shortcomings cited, to propose remedies for the deficiencies and to develop more efficient designs and approaches to increase the reliability and habitability of the shelter, as well as to decrease the time and effort required to erect and strike the shelter. Four main problem areas were identified; container jacks, floor jacks, leveling procedure, and floor deployment procedure.

## CONTAINER JACKS

The present container jack, Figure 3, is a modified screw-type commercial item with a mass of approximately 12.5 kilograms (27.5 pounds), capable of a 46-centimetre (18-inch) lift adjustment. It engages the shelter at two points. The bottom fixation point is a heel on the jack which is placed in the bottom side ISO fitting aperture. The top fixation point is a bolt head which is placed in a slotted connector on the container approximately 71 centimetres (28 inches) above the ISO fitting. The container is raised or lowered by rotating the screw head protruding through the jack with a special wrench supplied. The lifting force is applied through the bottom connection and the top connection provides stability. Four jacks are utilized to level and support the main section of the shelter.

The specific problems associated with the container jacks were further identified as:

- Not easily set on slope.
- Can not be deployed while on mobilizer.
- Shelter-jack connection failures.
- Excessive jacking required.
- Not universal for all ISO shelters.
- Jack handle failures.

2. Alexander, Charles L., Cpt, 50-Foot Expandable ISO Shelter, Report No. FM 302, 14 September 1976, Headquarters, TRADOC Combined Arms Test Activity, Fort Hood, Texas 76544.

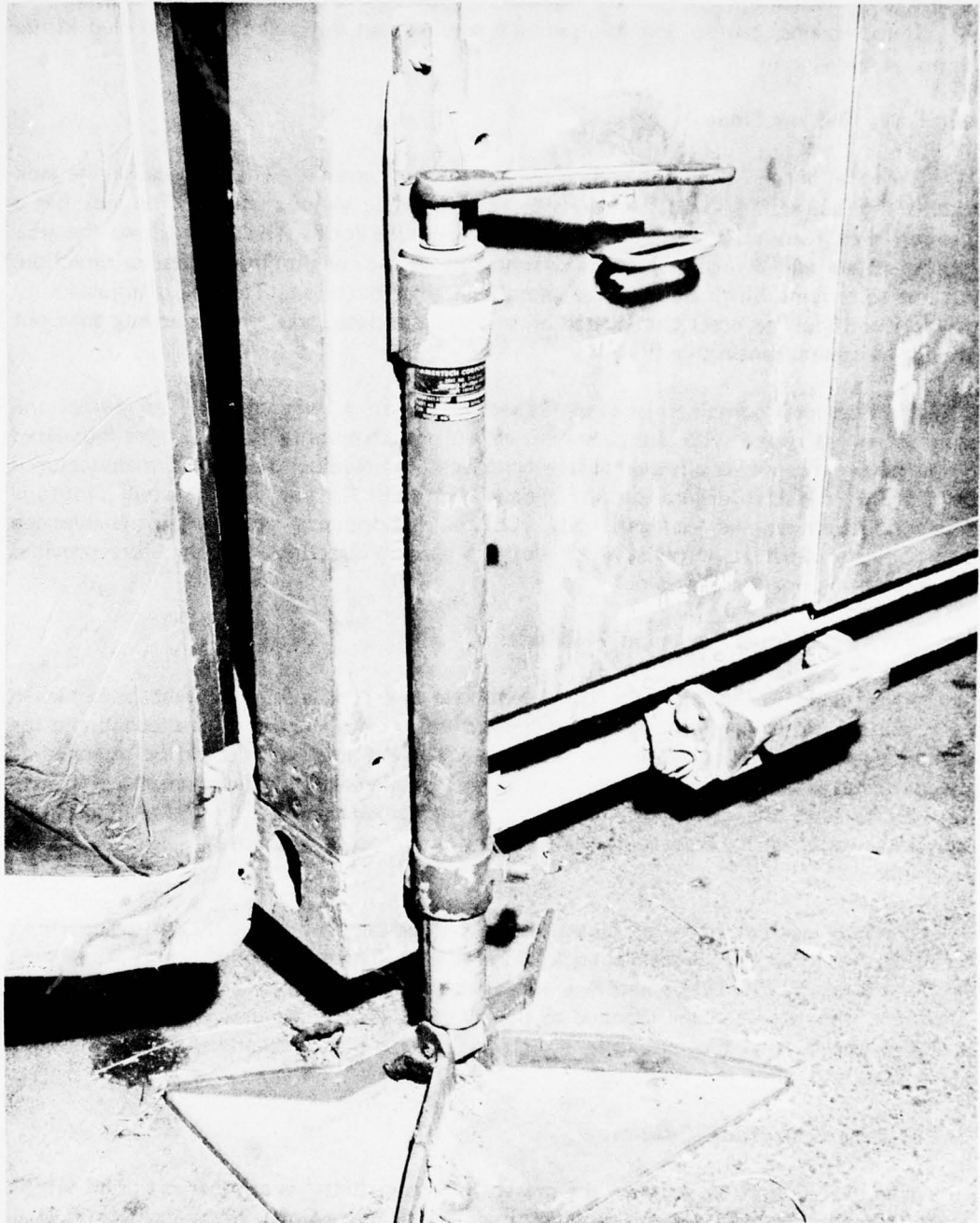


Figure 3. Container Jack.



The problems, causes, and solutions are summarized in Table 1 and detailed in the following paragraphs:

#### **Not Easily Set on Slope:**

The jack does not sit flat and secure on sloping terrains. This is because the jack foot is not adjustable in all directions to accommodate various slopes. The jack has a one-degree-of-freedom joint between the body and the foot. The joint allows the jack foot to rotate and adjust to terrains which slope in the longitudinal container direction, but not to terrains which slope in the lateral container direction. The lack of adjustability makes it difficult to erect the shelter on a sloping surface, and when erected, does not provide a secure footing.

An improved container jack configuration, Figure 4, was designed to correct the deficiencies associated with the present item. A prototype unit, Figure 5, was fabricated by modifying a commercially available leveling jack, Part Number 31030-18, manufactured by Saginaw Products Corporation of Saginaw, Michigan. The new jack has a ball-joint-type connection between the foot and body. The multiple-degree-of-freedom joint enables the jack foot to adjust to terrains which slope in various directions and therefore provides a firm footing for the container.

#### **Can Not be Deployed while on Mobilizer:**

After being towed to a site on a mobilizer the container must first be detached from the mobilizer and lowered to the ground before the jacks can be attached and the shelter leveled. Leveling would be much easier if the four jacks could be attached to the container while on the mobilizer because the mobilizer leveling mechanism could then be used to level the container. Once the container was leveled on the mobilizer, the jack feet would be lowered to the ground and the mobilizer removed, leaving a leveled container.

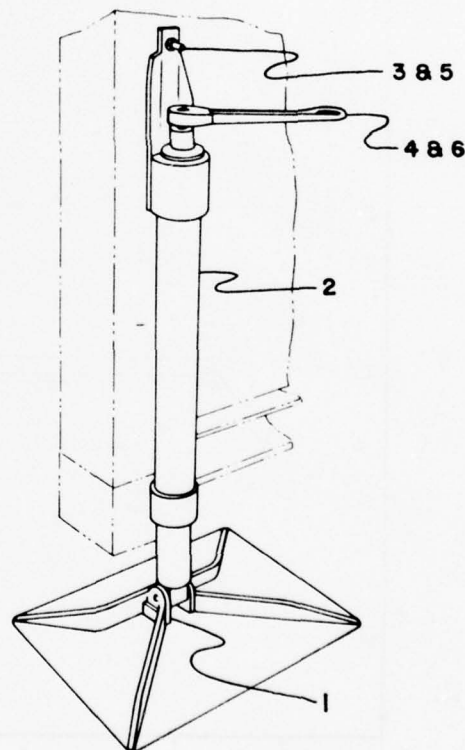
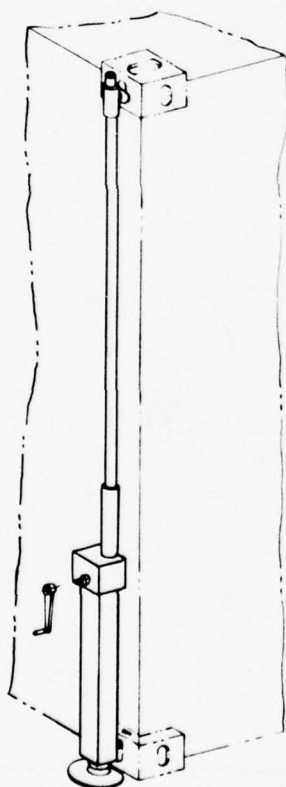
The new jack configuration allows the jack to be attached to the ISO fitting apertures on either the end or the longitudinal side of the shelter. The mobilizer obstructs attachment of the jack to the ISO fitting end face apertures but not the ISO fitting side face apertures. Therefore, the jacks can be attached to the ISO fitting side apertures while the container is still in the jaws of the mobilizer, thereby decreasing both the time and effort required to remove and level the container.

#### **Shelter-Jack Connection Failures:**

The top connection between the present jack and shelter is a vulnerable point subject to failure due to the large forces which may act at this point. When the jack is at or near the fully extended position and the shelter is located on sloping terrain, side forces are generated at the foot, transferred through the jack which acts as a lever, the heel

TABLE 1. CONTAINER JACKS

<u>PROBLEM</u>	<u>CAUSE</u>	<u>SOLUTION</u>
1. NOT EASILY SET ON SLOPE	1. ONE DEGREE OF FREEDOM FOOT	1. TWO DEGREE OF FREEDOM FOOT
2. CAN NOT BE DEPLOYED WHILE ON MOBILIZER	2. MOBILIZER OBSTRUCTS JACK LOCATION	2. RELOCATE JACK TO SHELTER SIDE
3. SHELTER/JACK CONNECTION FAILURES	3. EXCESSIVE FORCES GENERATED	3. LONGER LEVER ARM
4. EXCESSIVE JACKING REQUIRED	4A. TEN MOVEMENTS PER CENTIMETRE LIFT B. PUSH - PULL OPERATION	4A. FIVE MOVEMENTS PER CENTIMETRE LIFT B. CONTINUOUS OPERATION
5. NOT UNIVERSAL FOR ALL ISO SHELTERS	5. DESIGNED SPECIFICALLY FOR ACCORDION	5. NEW DESIGN FOR ALL ISO SHELTERS
6. JACK HANDLE FAILURES	6. HANDLE TOO LIGHT	6. REDESIGNED



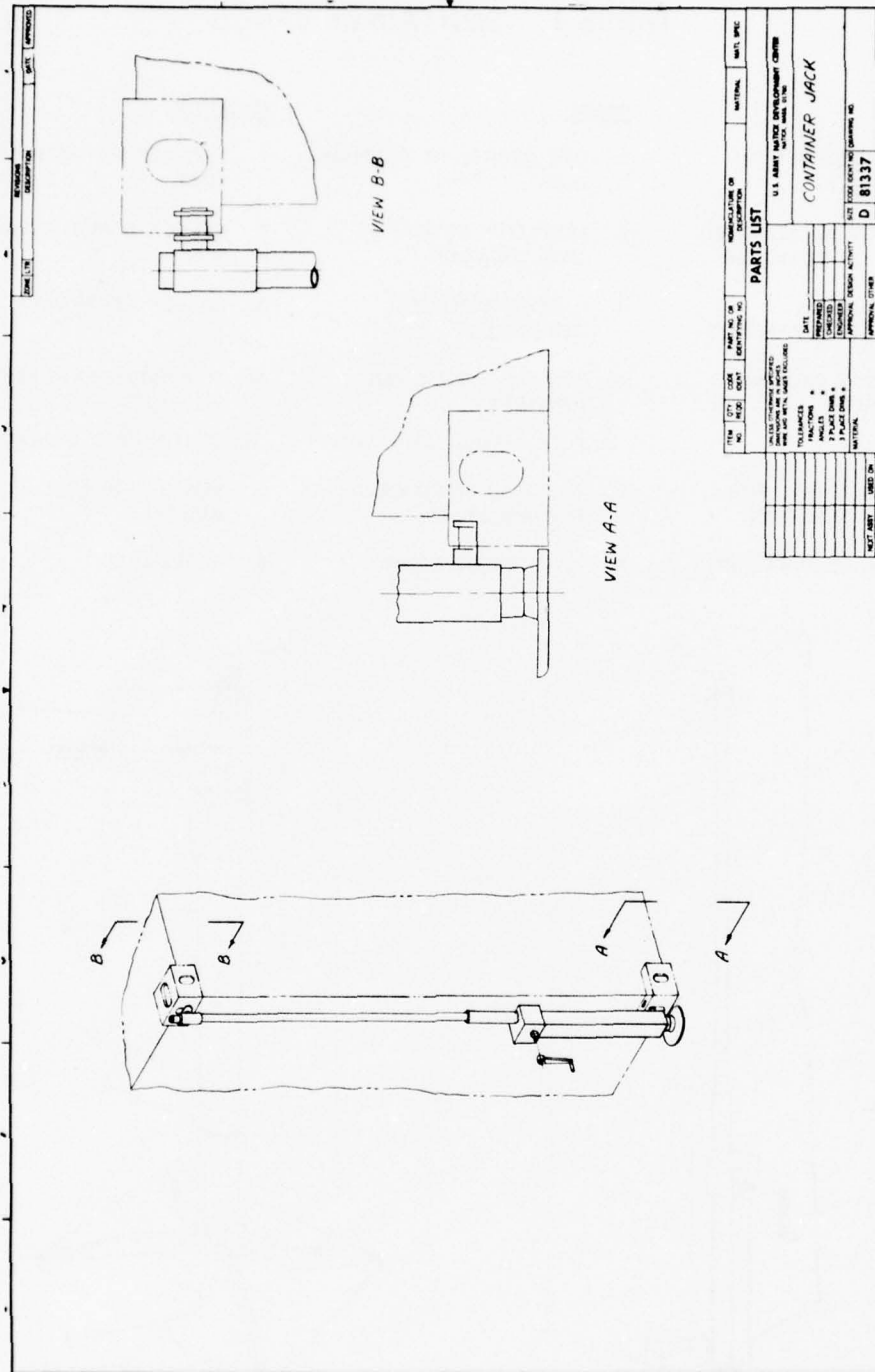


Figure 4. Improved Container Jack Design.



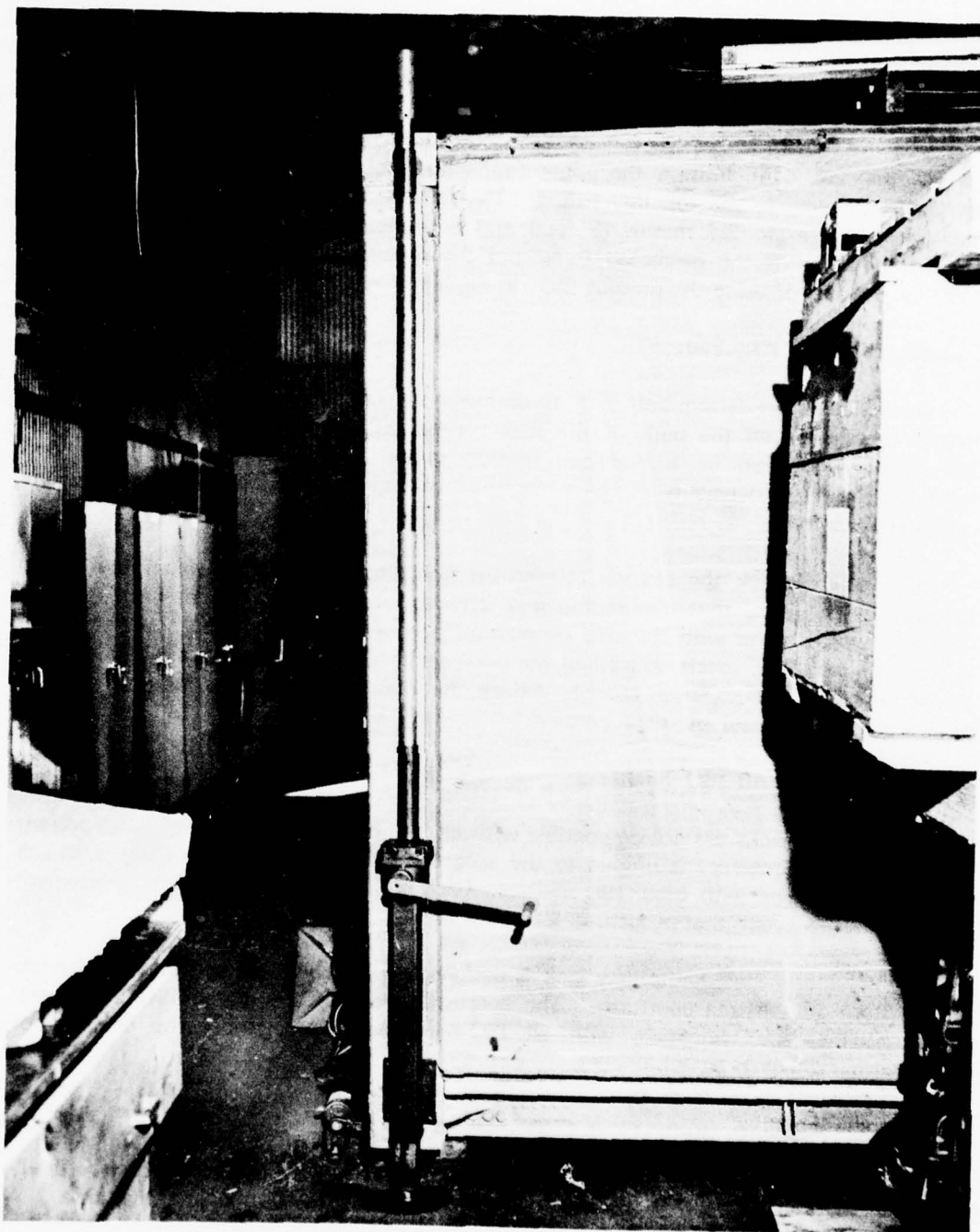


Figure 5. Improved Container Jack Prototype. Modified Jack Mounted on Side of Closed Shelter.

serving as a fulcrum, and are resisted by the top connection. The forces generated are sometimes sufficient to damage the top connection because of the relatively short length of the top lever arm, approximately 71 centimetres (28 inches).

In the new configuration the upper connection point has been relocated from the container end wall to the top ISO fitting. The relocated attachment point increases the resistive lever arm to 2.4 metres (8 feet) and decreases the force acting at this point. The combination of the decreased force and the increased strength of the connection point, as a result of using the present ISO fitting, eliminates the connection point failures.

#### **Excessive Jacking Required:**

Excessive effort is required to raise or lower the container with the standard jack. Interferences between the path of the jack handle and the container wall require that the jacking operation be a push-pull motion rather than a continuous motion and consequently ten movements of the wrench are needed to raise the container only one centimetre.

On the new jack the wrench attachment point has been moved from the top to the side of the jack, thus eliminating interferences, and the wrench has been replaced with one which mates with the side connection point. The wrench can now be rotated in a continuous 360° circle instead of the previous back-and-forth motion which covered an arc of only 170°. These changes reduce the number of motions required to raise or lower the jack heel by fifty percent.

#### **Not Universal for All ISO Shelters:**

The present jacks are not compatible with all ISO-type tactical shelters. The present jack-to-container interface is unique to the accordion shelter, and consequently jacks can not be interchanged with other ISO shelters. Lack of standardization makes replacement difficult in the event that a jack is lost or fails.

As previously stated, the new jack is designed to attach to the container at the top and bottom ISO fitting apertures. The apertures are standard on all ISO containers; therefore, the jack will mate with all ISO-type tactical shelters. The problem of incompatibility has been eliminated.

#### **Jack Handle Failures:**

The present jack handle has a history of service failures. The jack handle is structurally underdesigned, splits open in use, and can no longer be used to adjust the jack.

The new jack handle design is stronger than the previous model and should prevent the inservice failures which had been experienced.

## FLOOR JACKS

The present floor jack, Figure 6, is a specially manufactured item with a mass of 12 kilograms (27 pounds) capable of a total of 48 centimetres (19 inches) of vertical lift adjustment. Thirty-six centimetres (14-1/2 inches) of coarse height adjustment are available in 12-centimetre (4-3/4-inch) increments by extension of the proper number of telescoping sections which can be fastened into position with locking pins. The last 12 centimetres (4-3/4 inches) of adjustment are achieved by rotating the square head of the internal screw from above, causing the top section of the jack to move in relation to the foot. Twelve jacks, six on each side, are used to level and support the expanding floor. When not in use, the jack telescopes down upon itself and stands 20 centimetres (8 inches) high for storage.

The following problem areas were identified in the present floor jack:

- Adjustment screw loss.
- Engagement head failure.
- Poor footing.
- Locking pin loss.

The problems, causes, and solutions are summarized in Table 2 and detailed in the following paragraphs.

### Adjustment Screw Loss:

When the jack is being closed (lowered), sufficient torque can be applied to the fine adjustment screw to drive it past its normal travel limit. This causes the retaining ring to flip off and allows the jack screw head to slip inside the assembly. Once the screw falls into the assembly, the wrench can no longer engage the screw and the jack is inoperative.

Three conditions combine to cause this failure. The operator is inside the shelter when leveling the floor jacks and can not see the direction the jack head is moving. Consequently, the jack head can mistakenly be driven down instead of up. The jack screw is then driven past its normal travel limit because the screw does not have a positive stop to limit travel. As the screw is advanced past the design limit, the forces generated create a couple, which flips the retaining ring off. With the loss of the retaining ring, the jack screw is free to slip inside the assembly, and the jack is inoperative.

The floor jack was modified as shown in Figure 7 to eliminate this and the other problems cited. As part of the modification, the jack screw was replaced with a new jack screw, Figure 8, which has a shoulder that is designed to carry the bushing without damage and positively stop screw motion at the end of travel. The plastic floor caps

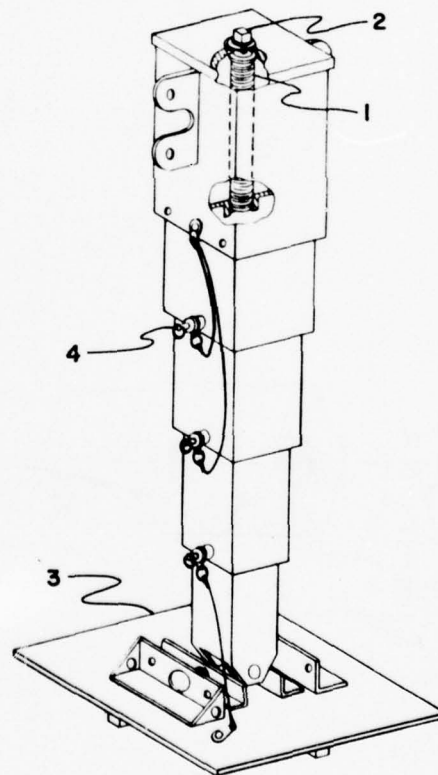
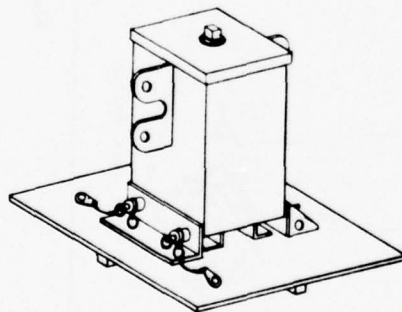


**Figure 6. Floor Jack. Partially Expanded Jack Attached to Floor Beam.**

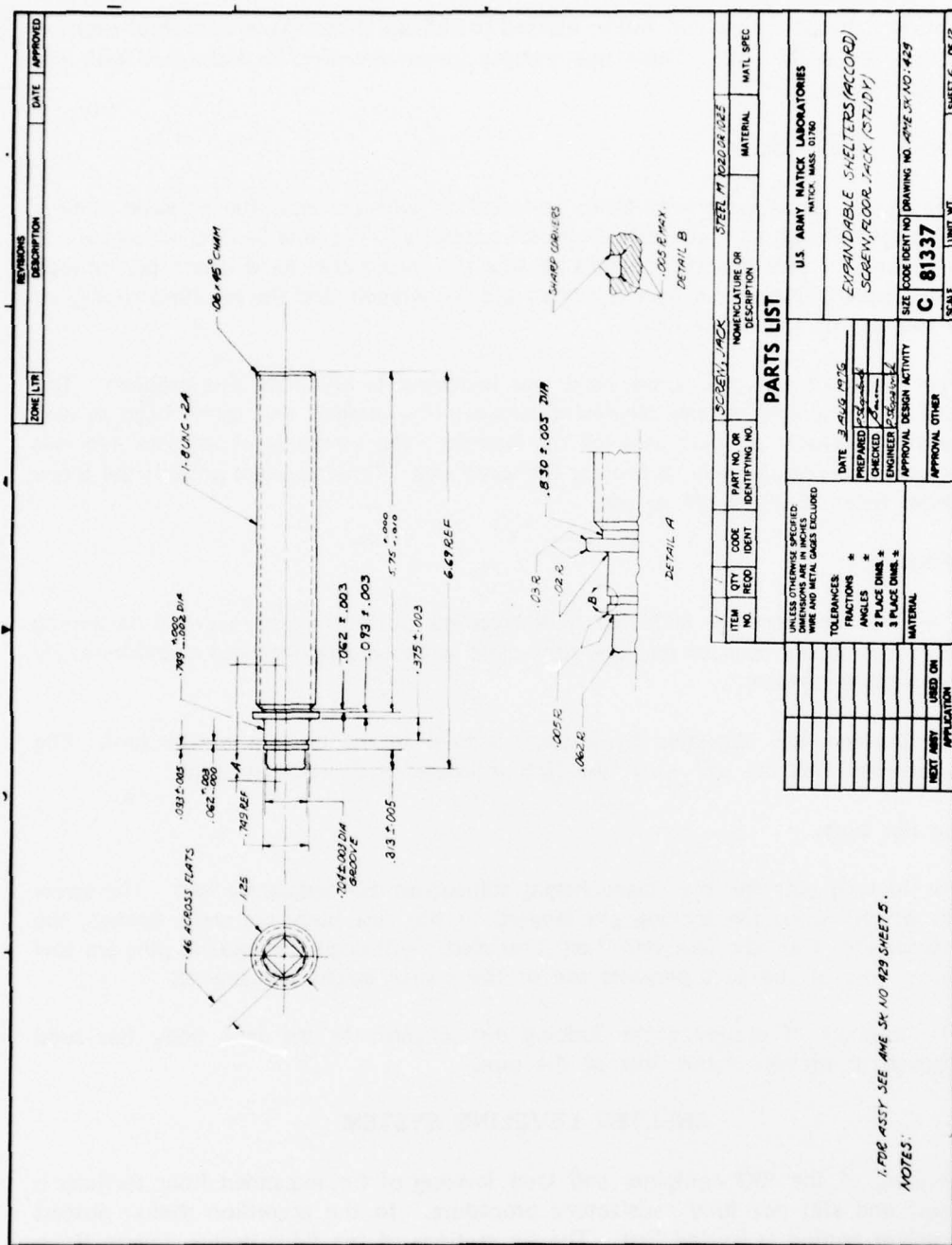


TABLE 2. FLOOR JACKS

<u>PROBLEM</u>	<u>CAUSE</u>	<u>SOLUTION</u>
1. JACK INOPERATIVE DUE TO LOSS OF SCREW	1A. NO UP/DOWN MARKING B. NO POSITIVE STOP RETAINING RING LOST C. INCORRECT BUSHING SEAT	1A. MARK B. MACHINE STOP C. CORRECT BUSHING INSTALLED
2. JACK INOPERATIVE DUE TO FAILURE OF SCREW ENGAGEMENT END	2. INADEQUATE ENGAGEMENT AREA	2. INCREASE LENGTH
3. JACK FOOT SLIDE	3. NO POSITIVE GROUND ENGAGEMENT	3. ADD CROSS
4. LOCKING PIN LOSS	4. INADEQUATE RETENTION STRENGTH	4. INCREASE STRENGTH







which protect the jack screw will also be marked to indicate the proper direction of rotation to raise and lower the jack. These two changes correct the problem associated with loss of the jack screw.

#### **Engagement Head Failure:**

The square engagement head tends to round off with use and after a period of time will no longer engage the adjustment wrench correctly. The fine jacking adjustment is then inoperative. This condition occurs because the engagement head is not long enough to assure proper alignment between the head and the wrench, and the resulting misaligned torque rounds off the screw head.

The length of the jack screw head was increased to eliminate this problem. The increased length assures proper alignment between the wrench and screw head as well as providing a greater gripping area for the wrench. The thickness of the jack top was also increased correspondingly to protect the screw end. These changes prevent the screw head from being rounded off in use.

#### **Poor Footing:**

The floor jacks tend to slide out of the vertical position when mounted on sloping terrains. This occurs because the jack foot plate is flat and smooth and therefore easily slips on sloping surfaces.

The problem was alleviated by welding a cross to the bottom of the foot. The cross protrudes into the soil when the jack is loaded and resists slippage.

#### **Locking Pin Loss:**

The locking pins for the coarse height adjustment are frequently lost. The screw and tab which attach the locking pin lanyard to the jack body are easily broken, the pin is separated from the jack and then misplaced. Although the locking pins are low cost items, loss of the pins prevents use of the coarse height adjustment.

The method of attaching the locking pin lanyards to the jack body has been strengthened to prevent future loss of the pins.

### **SHELTER LEVELING SYSTEM**

Leveling of the ISO container and later leveling of the expanded floor sections is a difficult and still not fully satisfactory procedure. In the accordion shelter process the container section is leveled first. The six sections of the floor beams, Figure 9, on each side of the shelter are then leveled. The expanded floor is then laid in position and the floor beams are releveled as necessary.



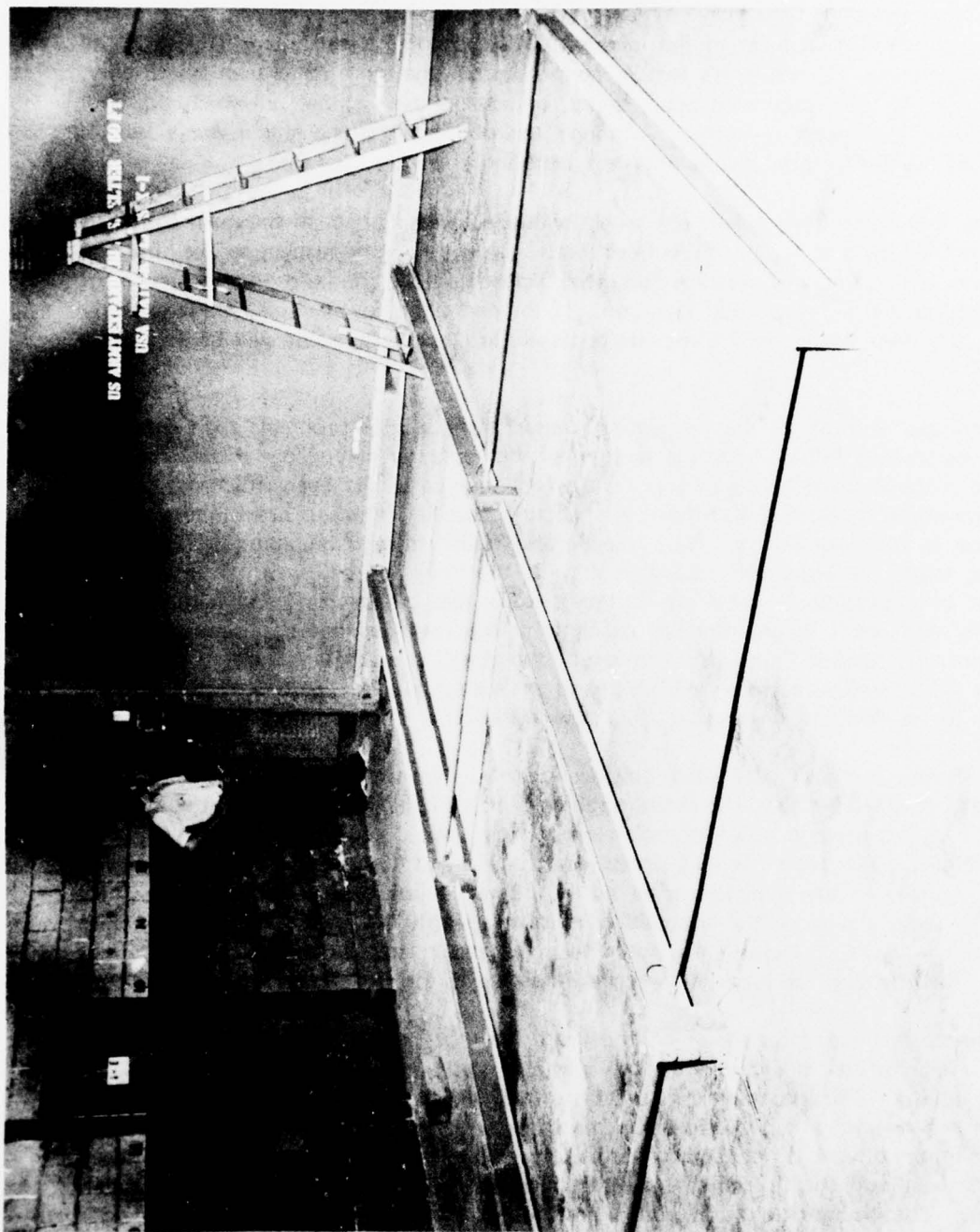


Figure 9. Accordion Shelter Foundation. Six Sections of Floor Beams Attached to Six Floor Jacks with Four Stabilizer Bars. Expanded Floor is Laid on this Foundation.

A mason's level, subject to the inherent deficiency of the instrument, is used in the leveling operation. The mason's level is correct within the range of its own length only. Any local deformity such as a bend, bump, or bow in the member on which the level is positioned will cause an error. Although the points on which the mason's level is placed are level, the total member is not necessarily level.

The first three floor beams are generally leveled with respect to the main container body and the second set of three floor beams is leveled with respect to the first set. Therefore, the accuracy of each measurement depends on the one before it, and any error is compounded throughout the operation. If the container, for example, is not properly leveled, the floor beams, which use the container as a reference point, will be impossible to level.

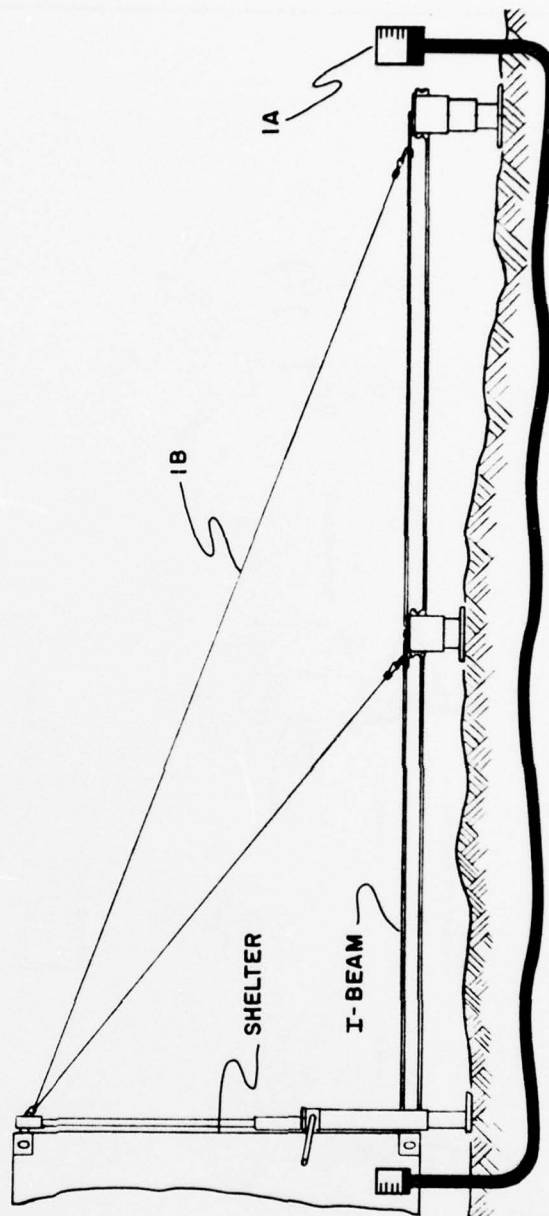
Improper leveling of the foundation causes more serious problems than merely a sloping or rocking floor. Improper leveling of the container may wedge the shelter sides in place in the shipping configuration. They must then be forced open which can damage the honeycomb panels and also result in a safety hazard if the panels break free suddenly and drop to the floor beams. Poor leveling also results in misalignment of the fasteners used to secure the expanded accordion shell to the floor and end wall. This makes it difficult or impossible to mate the fasteners, can cause overstressing and failure of the fasteners, and result in an interface which is neither weathertight nor blackout proof. An improperly leveled foundation can result, therefore, in a safety hazard to personnel, damage to the shelter, decrease habitability of the shelter and also cause the entire erection process to be difficult, frustrating, and time consuming.

Two new methods of leveling the accordion shelter were proposed, (see Table 3) and prototyped. One method is based on the principle of height difference of two selected points. In this method one foundation supporting point, i.e., container jack, is chosen as a reference. The other fifteen jacks (three container and twelve floor) are then adjusted, one at a time, to the same elevation as the reference jack. If each supporting point is at the same elevation, the foundation must necessarily be level. Local deformities between the jacks, therefore, do not affect the result and individual errors are not accumulative because each jack is leveled in reference to the one chosen bench mark point.

The correct elevation to which the jacks must be adjusted can be indicated by a device similar to that in Figure 10. Two identical graduated cylinders are connected with flexible tubing. The assembly is placed on a level surface and filled up to a convenient reference mark with a suitable liquid. One cylinder is attached to the bench mark jack, and the other cylinder is attached to the jack to be leveled. The jack is raised or lowered until the height of the fluid in the cylinder reaches the reference mark on the graduated cylinder. The two jack-fixation points are then at the same elevation. The process is repeated for the remaining jacks, always referring back to the same reference jack. When all the jacks have been brought to the same elevation, the foundation is level. A standard correction factor is applied when adjusting the floor jacks to the container jacks to account

TABLE 3. SHELTER LEVELING

PROBLEM	CAUSE	SOLUTION
1. DIFFICULT AND TIME CONSUMING TO LEVEL SHELTER	1. INHERENT INACCURACY IN MASON'S LEVEL OVER LONG DISTANCES - LEVELING SHORT PORTION ONLY OF POSSIBLY DEFORMED BEAM	1A. HEIGHT DIFFERENCE TECHNIQUE OR 1B. PREMEASURED CABLES - LOWER JACKS DOWN







for floor thickness and leveling device mounting position.

The second proposed method of shelter leveling is based on the use of premeasured cables as depicted in Figure 11. One end of the cable is terminated with a round hook which is inserted into a mating hole in the top longitudinal container beam perpendicularly above the centerline of a floor beam. The other two ends of the cable are terminated with double hooks which can be hooked onto the floor beams near the floor jack attachment points. In use, the container body is first leveled by conventional means. Three sets of cable levelers are then attached to the container upper longitudinal beam, and the floor beams are hung from the other ends of the cables. The cables are premeasured to assure that the plane of the floor beams is parallel to the floor of the container. At this point the suspended floor jacks are freed, and the feet are allowed to telescope to the ground where they are adjusted and locked. The cable assemblies are then removed and the folded floor is lowered into place on the leveled beams. The process is repeated to level the other side of the shelter.

Both leveling systems were prototyped and tested, and the cable system was judged superior based on its simplicity.

#### FLOOR/END WALL EXPANSION AND STRIKING TECHNIQUE

After the floor beams are fastened in place and leveled, the floor and end wall are unfolded, expanded and erected. This is accomplished, as shown in Figure 12, with a series of winch and pulley operations. A pulley and winch are connected between each end of the container and the outboard honeycomb panel. The four folded panels are lowered as a group to the horizontal position on the foundation beams by simultaneously releasing cable from both winches. The end wall is raised by hand to the vertical position and a temporary brace installed. The winch cables are then attached to the corners of the middle floor panel, which is raised and pulled over the center of the second hinge line. The winch cables are then attached to a connector between the outboard floor panel and the end wall, as a safety restraint, and the panels are manhandled into the open position. The ceiling beams are then installed and the accordion shell expanded and secured to the container, floor, and end wall. The sequence is repeated to deploy the other side and reversed to strike the shelter.

The specific problems associated with the expansion striking techniques were identified as:

- Cumbersome to raise/lower panels.
- Cable twists and frays.
- Difficult to expand, contract floor.

The problems, causes and solutions are summarized in Table 4 and detailed in the following paragraphs.

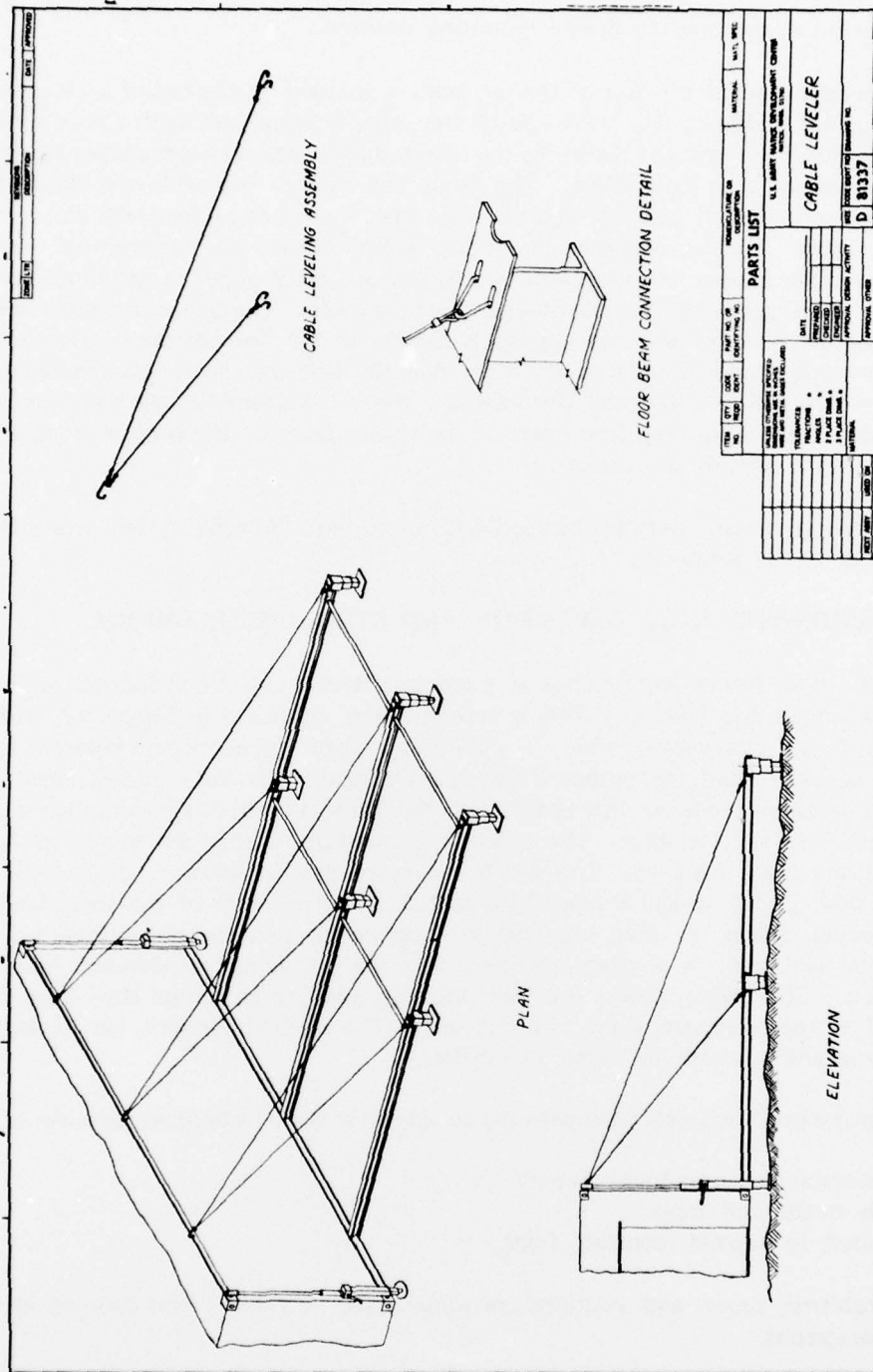


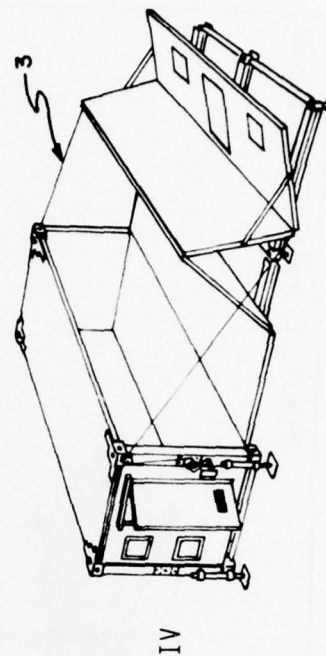
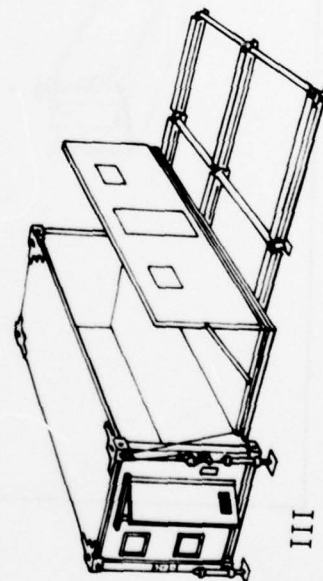
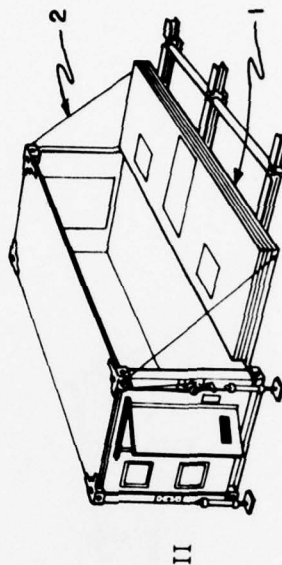
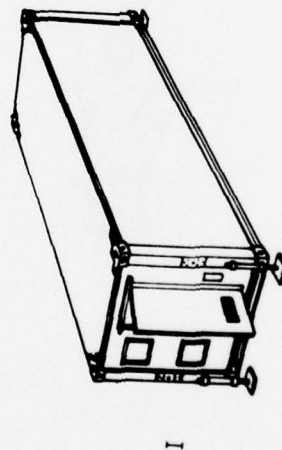
Figure 11. Cable Leveler.

ZONE		REVISIONS		DATE		APPROVED	
LTH		DESCRIPTION		DATE		APPROVED	
<b>PARTS LIST</b>							
ITEM NO.		QTY REQD	CODE IDENT	PART NO OR IDENTIFYING NO	NOMENCLATURE OR DESCRIPTION	MATERIAL	NATL SPEC
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES WIRE AND METAL ANGLES EXCLUDED							
TOLERANCES: FRACTIONS * ANGLES * 2 PLACE DIMS * 3 PLACE DIMS *							
MATERIAL							
DATE							
PREPARED CHECKED ENGINEER							
APPROVAL DESIGN ACTIVITY							
APPROVAL OTHER							
U.S. ARMY NATICE LABORATORIES NATICE NATICE GUNG							
PRESENT OPENING SYSTEM							
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SCALE UNIT WT. SHEET OF							

Figure 12. Shelter Expansion Technique.

TABLE 4. SHELTER DEPLOYMENT-STRIKING

<u>PROBLEM</u>	<u>CAUSE</u>	<u>SOLUTION</u>
1. CUMBERSOME TO RAISE AND LOWER PANELS	1A. SIMULTANEOUS TWO-WINCH OPERATION REQUIRED B. WINCHES LOCATED TOO HIGH, JACK OBSTRUCTION	1A. SINGLE WINCH SYSTEM B. RELOCATE
2. CABLE TWISTS & FRAYS	2. WRONG LAY	2. CHANGE MOUNTING CONFIGURATION
3. DIFFICULT TO EXPAND AND CONTRACT FLOOR	3. RAIL FRICTION	3. ROLLERS





#### **Cumbersome to Raise/Lower Panels:**

Lowering of the folded panels as a group onto the floor beams is a cumbersome operation for two reasons. First, the winches used to lower the panels are located approximately chest high. This is an awkward location for the operators because it is difficult to apply maximum force in this position. A preferable location would be approximately waist high where good leverage can be attained, but this is impossible because the container jack obstructs the location. Secondly, the panels should be lowered smoothly to assure that the load is evenly split between the two cables and uniformly distributed over the length of the hinge. This is difficult to achieve in actual practice because it requires perfect coordination between the two winch operators. Normally, despite the best efforts of both operators, the panels are lowered in a series of jerks with one winch or the other supporting the total load.

The operation was simplified by relocating the winch mounting position and utilizing a different winch and pulley arrangement as shown in Figure 13. In the new arrangement it was possible to locate the winch in the preferred position (container end, waist high) because the winch-jack interference had been eliminated by a previous change to the container jack which moved it to the container side. Less effort is required to operate the winch in the new position. The new arrangement also requires only one winch and therefore eliminates the problem associated with simultaneous winch operation and allows the folded panels to be lowered smoothly.

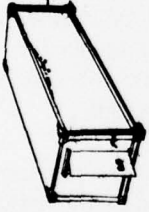

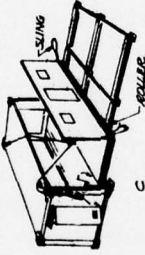

#### **Cable Twists and Frays:**

The cable itself was also identified as a problem area. The cable does not wind up on the winch drum uniformly, but tends to twist, overlap, and tangle on the drum as it is being retracted. Individual strands of the cable also break and fray with use. The frayed wires weaken the cable and can cause injury to operators.

The twisting of the cable and breaking of the wires is caused by the use of right lay cable instead of the left lay cable which is called for by the "underwind left to right" left anchorage winch-drum configuration. The problem can be eliminated by retaining the present winch-drum configuration and substituting left lay cable for the right lay cable. However, left lay cable is not always immediately available. A better solution would be to retain the right lay cable and modify the winch drum to an "underwind right to left" right anchorage configuration. This would eliminate the tendency of the cable to crisscross and overlap on the drum with the resulting damage.

#### **Difficult to Expand/Contract Floor:**

Once the three floor panels have been laid on the floor beams and the end wall erected with the temporary brace, the hinged floor panels are unfolded and spread out on the foundation beams. The unfolding operation normally requires five or six men; two to operate the winches and three or four to manhandle the panels and drag them

ZONE LTR		REVISIONS		DATE	APPROVED
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ITEM NO	QTY	CODE	DESC	PART NO OR IDENTIFYING NO	NOMENCLATURE OR DESCRIPTION	MATERIAL	MATL SPEC
<b>PARTS LIST</b>							
<div style="display: flex; justify-content: space-between;"> <div> <p>UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES WELD AND METAL JAMES EXCLUDED</p> <p>TOLERANCES</p> <p>FRACTIONS *</p> <p>ANGLES *</p> <p>2 PLACE DIMS *</p> <p>3 PLACE DIMS *</p> </div> <div> <p>DATE</p> <p>PREPARED</p> <p>CHECKED</p> <p>ENGINEER</p> <p>APPROVAL DESIGN ACTIVITY</p> <p>APPROVAL OTHER</p> </div> </div>							
<div style="display: flex; justify-content: space-between;"> <div> <p>U.S. ARMY MATRICK LABORATORIES</p> <p>DAVID, MISS, 0190</p> <p><b>PROPOSED OPENING SYSTEM</b></p> </div> <div> <p>SIZE CODE IDENT NO DRAWING NO</p> <p><b>C 81337</b></p> </div> </div>							
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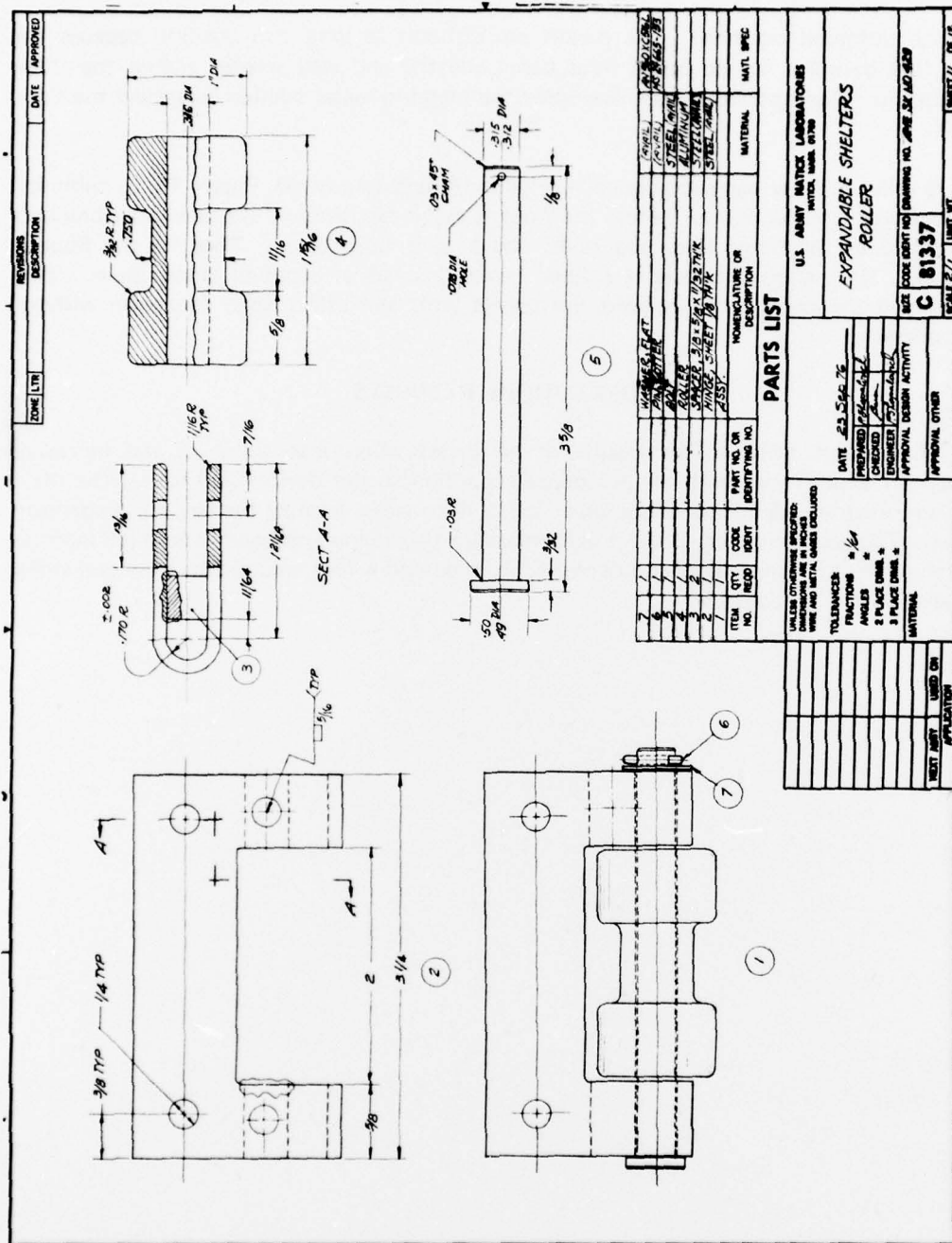
Figure 13. Revised Shelter Expansion Technique.

into the unfolded position. The panels are difficult to drag into position because the hinge line between the outboard floor panel and the end wall scrapes against the three floor beams. The operators must overcome the metal-to-metal friction to spread the floor panels.

A roller bracket has been designed, Figure 14, and fabricated, Figure 15, to minimize the frictional resistive force. Before the floor is expanded, three of the new roller brackets are pinned at the hinge line, one roller above each floor beam. Then, as the floor is expanded, the panels roll over the floor beams instead of scraping along them. Two men, using the rollers, can expand the panels with less effort than four men without the rollers.

### CONCLUDING REMARKS

This report presents the results of an investigation into some of the hardware difficulties experienced with the prototype accordion shelter during field tests. The main problem areas are identified as container jacks, floor jacks, leveling system, and expansion system. The specific causes of the problems are identified and improvements which increase the reliability of components and decrease the time and effort required to erect and strike the shelter are proposed.



**Figure 14. Roller Bracket Design.**



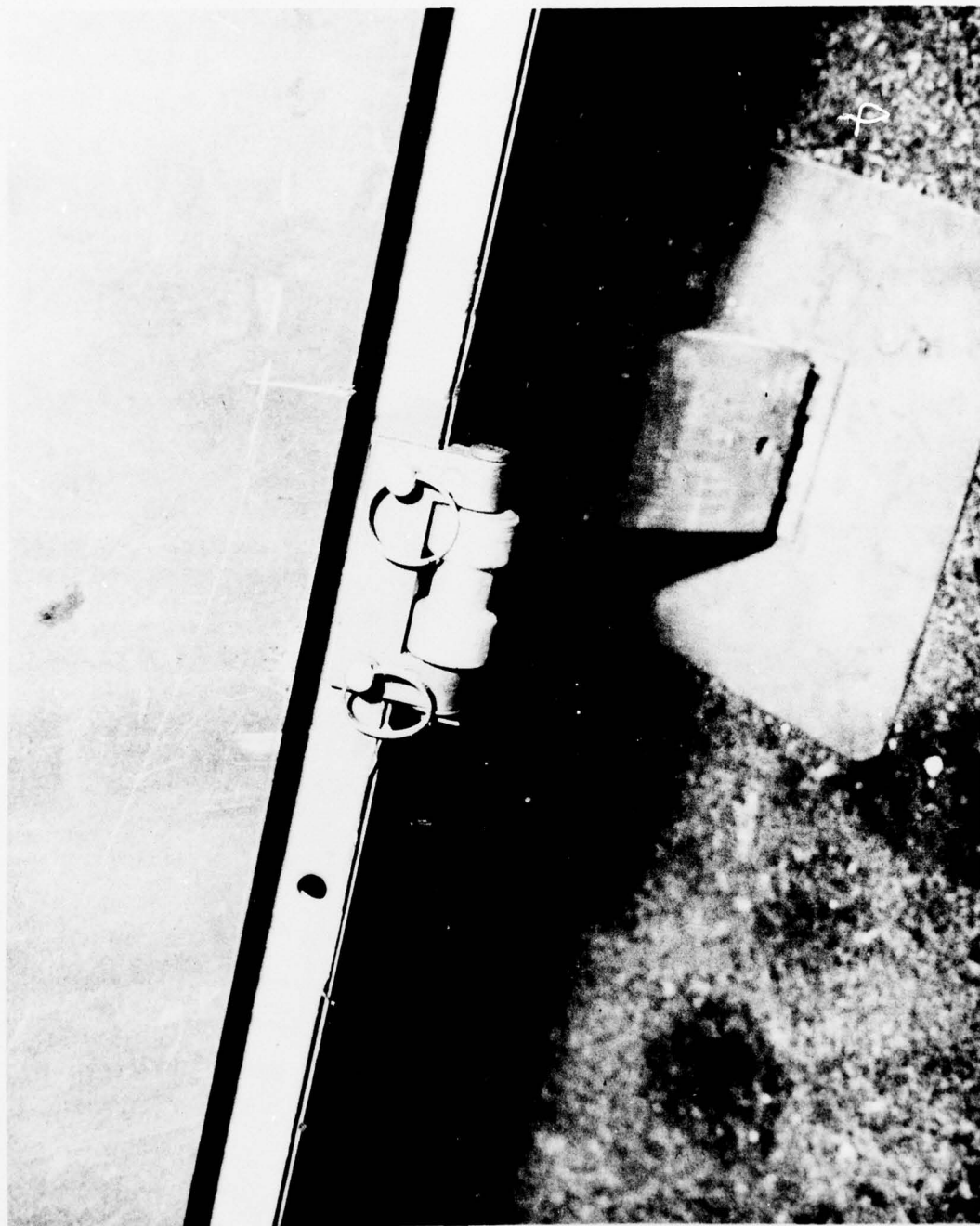


Figure 15. Roller Bracket. Roller Bracket Pinned to Hinge Between Expanding Side Wall and Floor.